Abstract. This paper presents a systematic micro-analytical study for the assessment of the influence of a typical hot-air “blow-in” heating system on the generation, transport and deposition of suspended particulate matter (SPM) in the church of Rocca Pietore (Italian Alps). This kind of heating system is very popular in cold regions due to its fast response and economic properties. The size, chemical composition and abundance of individual particles responsible for the negative impact on the displayed artworks are determined by ultra-thin window EPMA. EDXRF is used to determine the bulk chemical composition of SPM. Some gaseous pollutants (SO₂, NO₂ and O₃) are sampled with the application of passive diffusion tubes and quantified with ion-chromatography and spectrophotometry. It is pointed out that several deterioration processes, such as the abrasion of the plastered walls, the re-suspension of the particulate pollution and the generation of NO₂ gas, arise mainly from using the heating system. Each of these observations is a concern for the preservation of the displayed works of art.

Key words: EDXRF; EPMA; single particle analysis; size-fractionated aerosol samples; suspended particulate matter; diffusive gas sampling.
is widespread in mountain regions. The hot air is blown from two grid diffusers at 4 m above the floor level, which provokes an undesirable turbulence of the temperature and velocity fields, i.e. large driving forces that can be responsible for the deposition of particles on the cold surfaces of walls and works of art.

Several components of the ambient air can be considered as a potential threat to the preservation of paintings [2], e.g. organic materials which cause soiling, S-rich materials provoking the discolouration of paint, CaSO₄ constitutes a medium for blackening by adsorbing soot, and Fe-rich particles play a catalytic role in oxidation processes. On the whole, the adverse effects of heating on the structure and the contents of the churches are known [1]. It follows from the above considerations that the monitoring of the indoor air quality in buildings displaying works of art together with an assessment of the impact of their heating systems is of paramount importance from a conservation point of view. However, so far there has been no systematic study on the environmental conditions prevailing in historic churches caused by a heating process. Therefore, there is a lack of knowledge concerning the improvement of indoor conditions, i.e. to draw up guidelines and recommendations for conservation specialists and authorities, and to provide information for congregations of historic churches.

The bulk chemical characterization of the total suspended aerosol samples can easily be performed by energy dispersive X-ray fluorescence analysis (EDXRF). This method was successfully applied earlier by Camuffo et al. [2] to analyse aerosol samples collected in the Correr Museum, Venice, Italy. Injuk et al. [3] used EDXRF to determine the chemical composition of the aerosol samples taken in the Miyagi Museum of Art, Sendai, Japan. Electron-probe X-ray microanalysis (EPMA) is widely used to characterize aerosols at the individual particle level. Camuffo et al. [2] and Injuk et al. [3] applied this method to study airborne particles in the museums mentioned above. Both mentioned methods were used by Spolnik et al. [4] to study particulate pollution in the Cathedral of Weert, The Netherlands.

It had also been assumed that diesel-fuelled heating systems could be a source of different potentially aggressive gaseous pollutants, such as NO₂ and SO₂. These gases, when reacting with water (e.g. via taking humidity from the ambient air) are transformed into acidic compounds (sulphuric, nitric and nitrous acids). The importance of nitric acid, due to its aggressive nature, is self-evident [5]. Ozone (O₃), being a strong oxidizing agent, has been found to cause severe damage to textile dyes, paints and some pigments [5]. Thus, its monitoring in the ambient air of buildings displaying works of art is also a principal task. A convenient method for sampling of these gases is the application of passive diffusion tubes. Kontozova et al. [6] used diffusion tubes to estimate the concentration of these gaseous pollutants in museum showcases.

The international project “Friendly Heating” is dedicated to a multi-disciplinary investigation of the influence of the mentioned hot air “blow-in” heating system on the preserved works of art in the mountain church of Rocca Pietore. As a part of the project, the primary aim of our work was to characterize the bulk chemical composition of indoor and outdoor aerosols, as well as the size, chemical composition and abundance of single particles responsible for blackening and soiling of the works of art displayed within the church, and to point out the influence of the hot-air heating system on these deterioration processes. Moreover, the level of some relevant gaseous pollutants is also monitored inside and outside the church.

**Experimental**

Aerosol samples for the EDXRF and EPMA methods of analysis were collected from various locations inside the church (see Fig. 1) under two different conditions: when the heating system had been switched on for 1.5 h during the sampling period, and when it had been switched off. For the comparison of the indoor and outdoor air pollutants, several samples were collected outside nearby the church.

For the collection of bulk aerosol samples, Nuclepore filters of 0.4 μm pore-size and 47 mm diameter were used within a Millipore filter-unit connected to a low-volume vacuum pump (flow rate: 40 L min⁻¹). The average sampling time was 24 hours. The places chosen for the sampling are shown in Fig. 1.

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**Fig. 1.** Plan of the church